I. C. 6976 November 1937

UNITED STATES
DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

OPERATIONS AND COSTS AT THE ST. JOE MINING & MILLING CO., BOULDER, COLO.

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

OPERATIONS AND COSTS AT THE ST. JOE MINING & MILLING CO., BOULDER, COLO.[1]

By Jos. R. Guiteras[2]

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 6976."

[2] Mining engineer, metal mining methods section, Mining Division, Bureau of Mines.

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INTRODUCTION

This paper describes the operations of the St. Joe Mining & Milling Co. in Boulder County, Colo., as of June 1936. Later a brief visit was made to the mine in September 1936; information obtained at that time has also been recorded.

The company operates a gold mine, the Grand Republic, in the Sugar Loaf mining district; a 100-ton flotation mill in Lefthand Canyon near Gold Hill; and a custom sampling plant, the Boulder Ore Sampling Works, at Boulder, Colo.

ACKNOWLEDGMENTS

The writer is especially indebted to A. A. Zangara, president and general manager of the St. Joe Mining & Milling Co., through whose courtesy the paper was made possible. Grateful acknowledgment is also extended to E. M. LeVeque, secretary-treasurer of the company; to Joe Smith, mine foreman; to Ralph Foote, mill foreman; and to C. O. Larson, metallurgist and sampler foreman, who kindly furnished details of operation.

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BOULDER COUNTY[3]

Boulder County lies in the north-central part of the State of Colorado. The Continental Divide forms its western boundary. It is of somewhat rectangular outline, 33 miles long east to west, and 24 miles wide. Its area is 488,960 acres. The surface is extremely varied, being a rolling or broken valley in the east and rising to the summit of the Continental Divide on the west.

The first discovery of gold in Boulder County was probably made in December 1858 by a party of prospectors in Gold Run Gulch, on the west slope of Gold Hill. Placer mining flourished for about a year. Many gold-bearing veins in the vicinity were soon supplying surface ores to arrastres and stamp mills along Lefthand Creek. Successful recovery of the gold was limited to the oxidized ores. A smelter was built at Blackhawk in 1868 to treat the sulphides. Silver mining became important in 1869 with the location of the Caribou mine and the Poorman mine; the town of Caribou became the most prosperous in northern Colorado. Free gold was found in the Columbia vein at Ward in the late sixties. In May 1872, petzite, a gold-silver telluride, was found at the Red Cloud mine at Gold Hill. In March 1874 gold was found at Sunshine, 2 miles east of Gold Hill; the discovery resulted in the location of about 300 lodes. The next year, 1875, many discoveries were made along Fourmile Creek, Lefthand Creek, and South Boulder Creek and on Gold Hill. Most of the important lodes carried gold telluride or native gold, or both.

From 1876 to 1881, inclusive, the gold mines of Boulder County yielded an average of about $340,000 a year. In 1882 the Golden Age free-gold mine made Jamestown the principal district in Boulder County. The peak of gold production for the county was $982,988 in 1892. In 1933 more mines were producing in Boulder County than in any other county in Colorado. In 1935[4] there were 218 operating lode mines and prospects in the county, of which 116 produced only small lots of ore ranging from less than half a ton to 25 tons. The largest producer was the Grand Republic mine. The 1936 Minerals Yearbook records the gold produced in Boulder County during 1935 as 22,631.2 ounces; the silver production was 34,048 ounces.

CLIMATE[5]

According to the United States Weather Bureau, the mean temperature in Colorado for the last 45 years was 44.9°F. This includes extreme recorded temperatures of 115° in 1888 and -54° in 1913 and 1930. A record covering 35 years shows an annual mean temperature for Boulder of 50.6°, with a high monthly mean of 71.0° in July and a low monthly mean of 32.7° in January. The highest temperature recorded in Boulder during 1933 was 97° on July 28; the lowest was -19° on February 7.

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[3] Henderson, C. W., Mining in Colorado: Geol. Survey Prof. Paper 138, 1926, 263 pp.

[4] Henderson, C. W. and Martin, A. J., Gold, Silver, Copper, Lead, and Zinc in Colorado: Minerals Yearbook 1936, Bureau of Mines, 1936, pp. 243-279.

[5] Colorado Year Book for 1933-34, 1934, pp. 76-86.

For the last 46 years the mean annual precipitation for Colorado has been 16.62 inches. The 35-year record for Boulder gives a mean of 14.05 inches, with a high monthly precipitation of 2.90 inches in May and a low of 0.38 inch in February. The total precipitation in 1933 at Boulder was 16.08 inches. The greatest precipitation in any month of that year was 4.15 inches in April, and the least was less than 0.01 inch in January.

GEOLOGY[6]

Pre-Cambrian rocks are exposed in a north-trending belt some 30 to 40 miles wide. The city of Boulder lies in sediments bordering this belt on the east. Northwestward-trending faults characterize the eastern border of the belt. In the region west of Boulder are two large masses of granite separated by a belt of schist that trends southwest. A belt of cross-breaking porphyry stocks extends southwest-ward across the Front Range from Jamestown, 9 miles northwest of Boulder, to Breckenridge. The general geology of the region west of Boulder is shown in figure 1. Most of the ore deposits and most of the porphyry dikes of the mineral or porphyry belt of the Front Range occur on the southeast side of the belt of stocks, although at Ward and north of Jamestown the economically important ore deposits occur on the northwest side.

Lovering[7] states that "although the regional distribution of the ore deposits is dependent on the regional distribution of the porphyries, the localization of the ore bodies is directly related to faults and fractures that have made openings in the rocks through which the mineralizing solutions could ascend toward the surface."

The northwesterly faults are nearly vertical and are older than the cross-breaking porphyry stocks. The fault material is often highly silicified, and this fact has led the miners to regard the faults as "dikes." They are silicified fault breccias. A later series of relatively flat faults with a northeasterly trend has formed a persistent shear zone that in many places is mineralized. Most of the important gold and tungsten ore shoots in Boulder County occur at the intersections of faults within the shear zone. Such deposits are usually less than half a mile from one of the northwesterly faults. The ore-bearing solutions probably ascended through the northwesterly faults until they reached the more superficial shear zone of the northeasterly faults. Through the latter they moved toward the surface; the open nature of the ground encouraged the deposition of their mineral content.

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[6] Lovering, T. S., Preliminary Map Showing the Relations of Ore Deposits to Geologic Structure in Boulder County, Colo. Proc. Colorado Sci. Soc., vol. 13, no. 3, 1932, p. 80.

[7] See footnote 6.

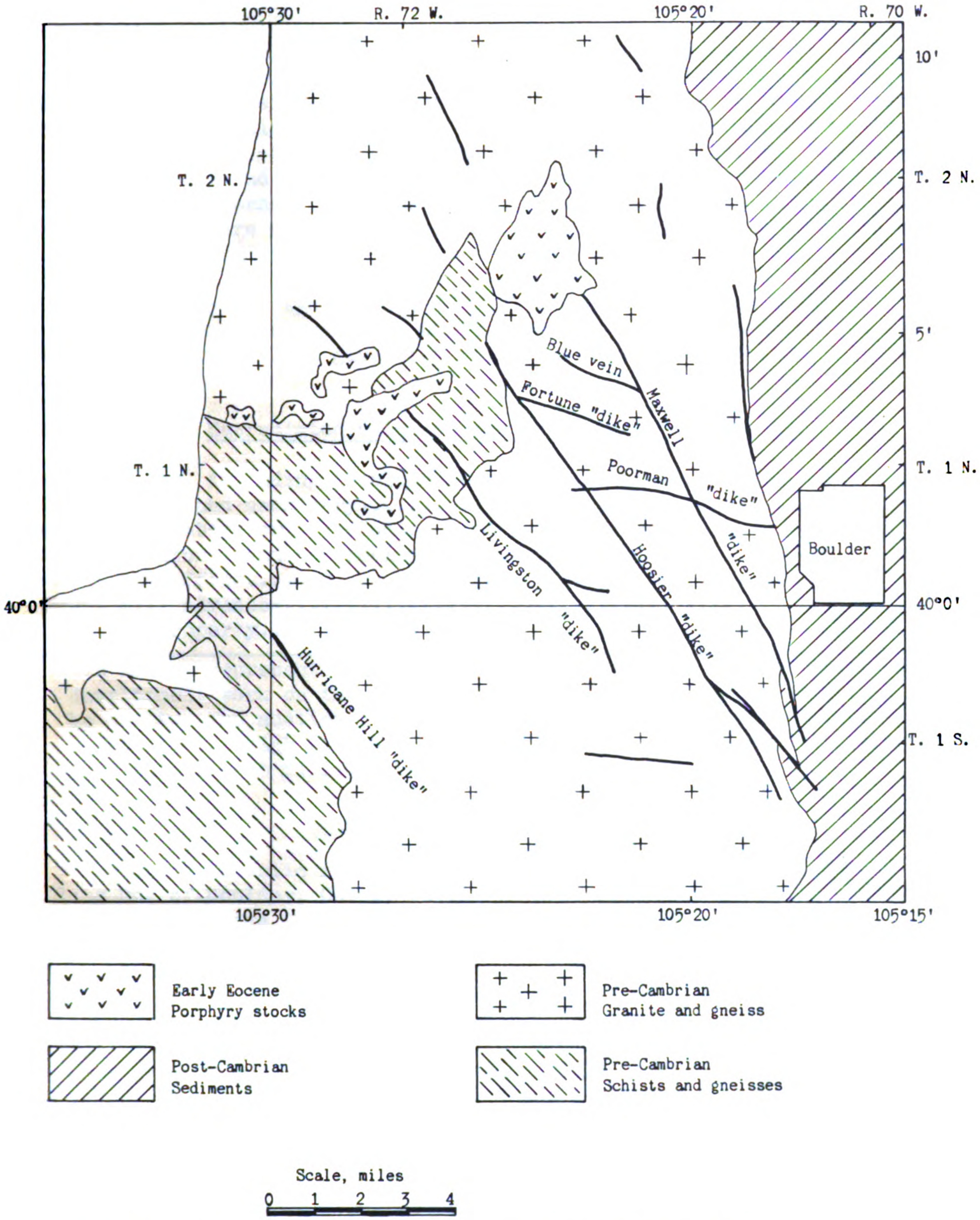

Figure 1.- Geology west of Boulder, showing northwesterly "dikes" (after Lovering).

ST. JOE MINING & MILLING CO.

The St. Joe Mining & Milling Co. was incorporated August 8, 1932, under the laws of Colorado, with an authorized capitalization of $250,000. Mining operations were started the following October. The company acquired several groups of mining claims in the country west of Boulder at a cost of about $250,000. Virtually all the ore mined by the company has been taken from the Grand Republic mine. Other mines owned by the company, notably the Tippecanoe and Belle mines, have yielded small tonnages intermittently; they are not considered in this paper. All the ore milled since March 1936 was from the Grand Republic mine.

The company has spent about $75,000 for developing the mines and equipping the various operating units. The auditor's report for the year ending December 31, 1935 gives the following depreciated values for these units.

Depreciated value of property, December 31, 1935

Mining claims, including development and equipment	$259,924.90
Mill building and machinery	27,741.79
Sampler and laboratory, including land and equipment	5,989.02
Trucks, tractors, and automobiles	8,884.85
General and office	762.86
Valmont mill advances	[1] 944.00
Total property	$304,247.42

---

[1] This amount represents engineering, labor, and salary costs covering development work on the site on which it is anticipated a new mill will be built. The auditor's report states, "The problem of tailings disposal and the high cost of mountain milling appear to make it imperative that the present mill be abandoned sometime in 1936."

Grand Republic Mine

The Grand Republic mine, owned and operated by the St. Joe Mining & Milling Co. of Boulder, Colo., is the largest producer in Boulder County. It is located in the SE 1/4 sec. 19, T. 1 N., R. 71 W., just outside the Roosevelt National Forest and near the intersection of the Hoosier and Poorman "dikes" (See fig. 1.) It is about 5 miles west of Boulder, in the Sugar Loaf mining district, at an altitude of about 7,000 feet. The property is reached from Boulder, via the Boulder Canyon Highway (U.S. 119) for 3 miles, then the Gold Hill road up Fourmile Canyon for 4 miles to Crisman, and finally a narrow road that crosses Fourmile Creek and climbs for a mile and a half in a general westerly direction; the total distance is 8-1/2 miles.

Characteristics of Ore and Rocks

The country rock at the Grand Republic mine is granite. It stands well in the stopes where it is mineralized and silicified. In the hanging wall it is soft and sloughs badly. The granite has been cut by many fissures; along some of them there has been movement. The fissure that is considered the footwall of the ore strikes about S. 70° W. and dips about 45° northwest. The hanging-wall fissure strikes nearly west and dips about 65° north. These two fissures diverge toward the west from their intersection near the main hoisting incline. The ground between them is traversed by many smaller fissures; some are quite flat and others nearly vertical. This fissured zone contains the ore bodies. A prominent fissure called the South Vein seems to terminate the ore zone on the west. Ore shoots within the fractured zone are sometimes terminated abruptly by a fissure; at other times the limit of mineralization is not well defined. The thickness of the ore ranges from about 2 to about 45 feet.

The gangue minerals are chiefly quartz and iron oxides. Pyrite is disseminated through the gangue as free grains and tiny particles. Small quantities of marcasite and arsenopyrite are present.

A 660-pound sample of ore from the Grand Republic mine, assayed for testing purposes in April 1936, showed the following composition:

Gold	ounces per ton	0.26
Silver	do.	.30
Lead	percent	0
Copper	do.	0
Iron	do.	5.84
Sulphur	do.	1.77
Arsenic	do.	.07
Insoluble	do.	81.20

The specific gravity of the sample was 2.66.

Most of the gold in the sample appeared to be in the form of tellurides associated largely with pyrite. Some native gold was identified. Silver was found in the tellurides and as native silver.

Prospecting, Exploration, and Development

The mine is opened by a one-and-one-half-compartment main incline in what is locally called the "plug," a name applied to the apparently barren ground east of the intersection of the hanging and foot-wall fissures. The slope of the incline is 65°, and the direction of dip is a little west of north. At distances of 50, 100, 160, and 220 feet, respectively, measured down the incline, crosscuts have been driven north to the hanging-wall fissure. On the 160- and 220-foot levels, the crosscut length is about 85 feet; on the upper levels it is a little less. Figure 2 shows the main underground workings.

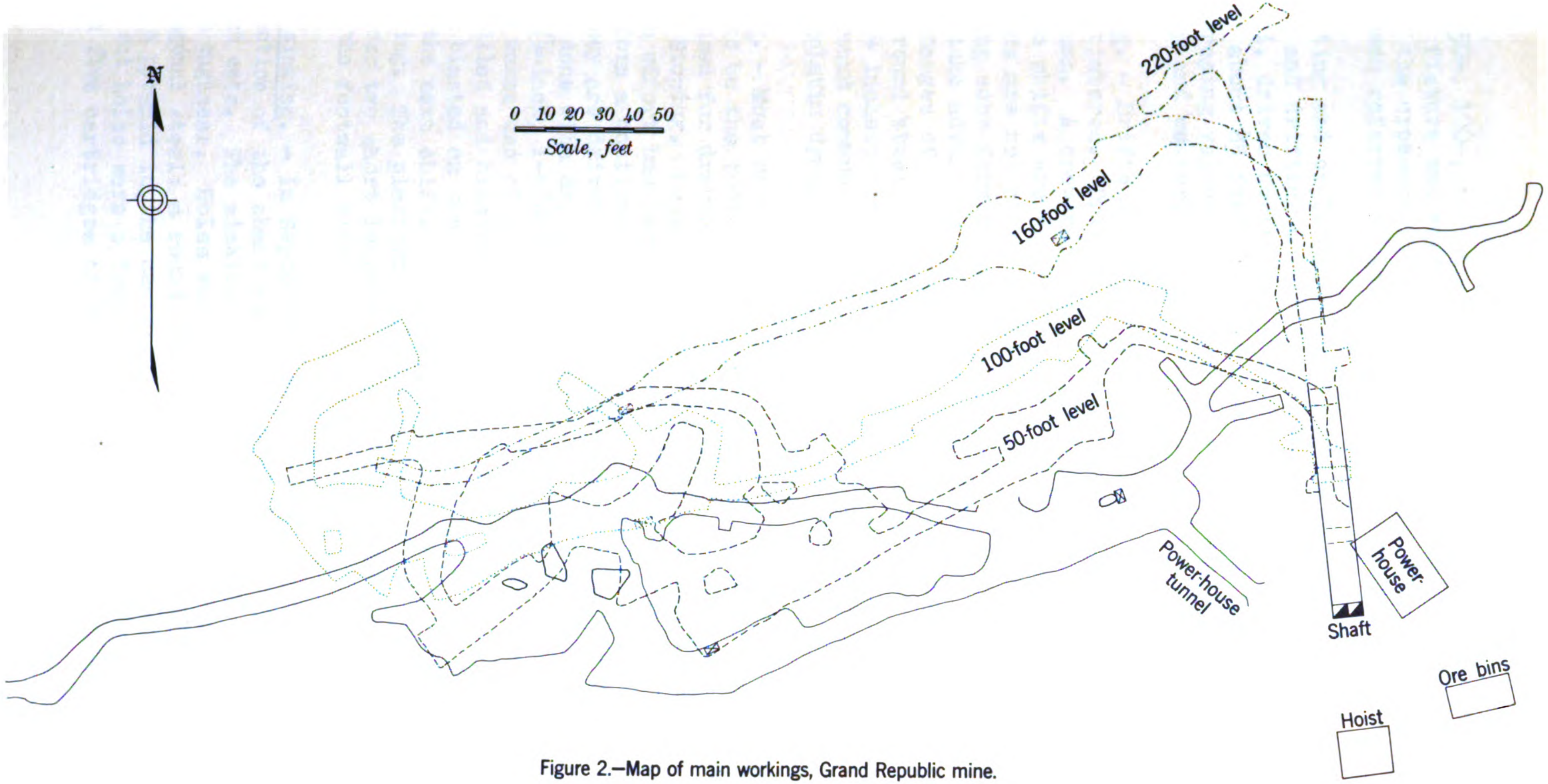

Figure 2.—Map of main workings, Grand Republic mine.

On the 50-, 100-, and 160-foot levels, drifts have followed the hanging-wall fissure westward. They cut the footwall fissure 40 to 80 feet west of the crosscut from the main incline. This intersection has previously been referred to as the east end of the ore zone.

Prospecting and exploration of the ore body in June 1936 comprised crosscutting and drifting on the 220-foot level of the mine. A crosscut on that level, driven north from the main shaft, intersected the hanging-wall fissure about 85 feet from the shaft. Samples taken from the fissure showed encouraging values in gold. Drifts were started along the fissure both easterly and westerly, as shown in figure 2.

Drifting. - Drifts and crosscuts are driven 5 by 7 feet in section and are not timbered. Drilling is done by a drifting machine mounted on a 6-foot column. A crew comprises a machineman and his helper and two muckers. Two shifts are worked; a round is drilled and blasted on each shift. Rounds are not standardized; usually from 16 to 20 holes are drilled, using some form of wedge cut. The miners modify the arrangement of holes to take advantage of fissures. The granite is easily drilled; only three changes of steel are required to drill the 7-foot holes. One-inch hollow round steel with cross bits is used. The diameter of starting bits is 1-3/4 inches; seconds are 1-5/8 inches, and finishers are 1-1/2 inches. A round commonly breaks from 5 to 6 feet with about 35 pounds of 40-percent gelatin dynamite.

Raising. - Most of the raising is done on the footwall fissure, which is thought to be the footwall of the ore body. It dips about 45°. Short raises are used for drawing the broken ore out of the stopes, as described later under Stoping. Longer raises are driven between levels for ventilation, and an effort has been made to keep these raises in line with one another to form a continuous connection. Raises are about 5 by 8 feet in section. They are driven by a machineman and a helper on each shift. Drilling is done with dry stopers, using 1-inch cruciform steel. Cross bits of 1-3/4-inch, 1-5/8-inch, and 1-1/2-inch diameters are used. The raise round makes use of a burned cut to which a V-cut breaks. The two cuts are drilled and blasted on one shift; the balance of the round is drilled and blasted on one shift; the balance of the round is drilled and blasted on the next shift. The men are supported on a temporary platform while drilling. The platform is built by laying two pieces of 2-inch lagging across two short lengths of old drill steel stuck into holes drilled in the footwall with a jackhammer.

Shaft sinking. - In September 1936 the main shaft was being deepened. The rock section of the shaft was 6 1/2 by 12 feet. The shaft was timbered with 10-inch sets. The sinking crew consisted of two men at the bottom and a hoist engineer. Holes were drilled with jackhammers using 7/8-inch hollow hexagonal steel; a round comprised 26 holes. Four cut holes were drilled to a pyramid in the center, and two were drilled to a V on each side. The cut holes were 6 feet deep; the others, 4 feet. Each hole was loaded with five cartridges of 40-percent gelatin dynamite. The cut holes were drilled and blasted, and the broken rock was removed first; then the rest of the round was drilled and blasted. Fuse and caps were used for detonating the charges. The granite was hard to drill but broke well. An average of 3 1/2 feet was broken per round. A cycle was made in four shifts; another shift was required for timbering. A sinking bucket was used in the east hoisting compartment of the shaft; it was dumped into the waste hopper in the head frame.

Mining

Stoping. - Stoping had not been done systematically in the old workings above the Power House level. Open stopes had been used, and where the width of ore justified it a glory-hole method had sometimes been followed. From the 50-foot level, open stopes were carried up to the Power House level; sometimes they broke through and at other times a thin pillar of ore was left to support the upper level. On the sill floor these stopes extended about 1,000 feet and reached a maximum width of about 45 feet in the south stope. A few vertical pillars about 10 feet in diameter were left in the south stope on the 50-foot level. The old stopes were silled out on the drift.

Later the ore was not silled out on the 100-foot drift, but two raises, about 30 feet apart, were driven up on the footwall and connected by an overcut, leaving a 10-foot pillar over the back of the drift. One of these raises was extended to the 50-foot level for ventilation. From the overcut, an open stope about 7 feet wide was carried upward on what was considered to be the footwall to within about 10 feet of the level above. While one of the two raises was being used for drawing off the ore, the other served as a manway and supply raise. In June 1936 no chutes had been built in the raises; the ore was shoveled off the floor of the drift into buckets on trucks. The average horizontal length of the ore shoot was about 50 feet. The ore was followed westerly from a point on the west end of the stope about halfway up from the 100- to the 50-foot level; this resulted in materially increasing the length of the stope. The 7-foot stope was planned to be a footwall slice of a much wider stope. Contrary to expectations, however, there was very little ore above the 7-foot slice; instead, the ore had cut through the fissure that had heretofore been regarded as the footwall of the ore zone. In September 1936 this ore was being followed by open stoping. Chutes had been erected in the main drift on the 100-foot level to receive the broken ore. One-ton cars had been substituted for the buckets on trucks for haulage to the shaft.

Underground haulage. - In June 1936 all rock broken underground was trammed by hand in 1,600-pound hoisting buckets supported in an inclined position on trucks. The buckets were lowered onto the trucks at the main hoisting shaft. They were loaded by hand and were tilted into position to bring the open end of the bucket toward the muck pile. All the shaft stations (except the bottom) had a door over each hoisting compartment of the shaft, hinged on the hanging-wall wide. The door was kept in a raised position to permit buckets to pass by in the shaft. When hoisting was to

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be done from a level, the door on that level was let down over the compartment that was to be used. Rails bolted to the door formed a continuation of the track on the station and thus enabled the truck to be rolled into the shaft compartment to receive the bucket. Most of the mine track is of 16-pound rails; considerable 12-pound and some 8-pound rails are used. The track gage is 18 inches.

In September 1936 all underground tramming was done by hand in 1-ton mine cars. Ore from stopes on the 100-foot level was loaded into the cars from chutes in the stope raises. Development waste was loaded into the cars by hand shoveling. The mine cars were dumped directly into a small skip in the west hoisting compartment of the main incline.

Hoisting. - In June 1936 hoisting was done by two electrically driven geared hoists housed in a small frame building near the head frame. One hoist was used for each of the hoisting compartments in the shaft. One was driven by a 30-hp. motor and used a 5/8-inch steel-wire rope; the other was driven by a 35-hp. motor and used a 3/4-inch rope. One man operated both hoists. The hoisting ropes passed over 3-foot sheaves mounted on a simple timber head frame 36 feet high. Buckets were attached to the hoisting cables by means of a chain and hook; they were dumped at the surface into a small hopper built into the head frame. The broken rock was drawn out of the hopper into 1-ton mine cars by a topman. It took about 1 minute to hoist a loaded bucket from the 160-foot level to the surface.

In September 1936 a small skip was used in the west hoisting compartment of the shaft. The head frame had been redesigned to permit ore to be sorted on a short grizzly ahead of an ore hopper. Waste from development and from sorting was dumped into another hopper.

Ventilation. - Natural ventilation, assisted by the exhaust air from the drills and pumps, provides good air for all working places. As only two shifts are worked per day there is opportunity for the gases resulting from blasting to be dispelled between shifts. No fans or blowers are used.

Drainage. - The mine makes a maximum of about 1,000 gallons of water per day during June. It makes only about 300 to 400 gallons per day after the first part of July and considerably less during the winter. This water is pumped to the surface by two small steam pumps operated by compressed air; one pumps from a small sump on the 160 level and the other from a small sump on the 220 level.

Surface Arrangements

Surface buildings. - In addition to the hoist house, there is a powerhouse which contains the compressor, machine and blacksmith shops, and a change house. All are grouped about the head frame. A five-drill air compressor, converted from steam to electric drive, delivers air at 100 pounds pressure to a series of three old boiler drums that are used as air receivers. The compressor is belt-driven by a 100-hp. motor. The air is used to operate a drill sharpener in the blacksmith shop and three machine drills and two pumps in the mine. It enters the mine through a 1-1/2-inch main air line.

There are no living quarters at the mine; the men live in nearby towns and go to work in automobiles.

Sorting. - In June 1936 virtually all the rock hoisted from the mine was handled as ore. It was drawn from the hoppers at the head frame into 1-ton cars, which were then trammed about 50 feet to the top of the mine ore bins. The bins are 24 feet long and 8 feet wide and are divided into three equal compartments. The surface track of 16-pound rails runs across the top of the bins. Figure 3 shows the general arrangements for sorting. All the ore was sorted except a small amount of wet fine ore, which was dumped directly into the first compartment by the topman. Ore to be sorted was dumped on a 3- by 16-foot grizzly that extended over the two other compartments. The grizzly was made of 3/4-inch bars with 2-inch spaces between; it served as a sorting platform. Two sorters worked on each shift. Large pieces of waste were thrown onto a 4- by 6-foot turnsheet or into a 1-ton car parked at the end of the track. Waste that accumulated on the turnsheet was shoveled periodically into the parked car. About 10 percent of the ore hoisted was sorted out as waste. Waste from sorting or from development work was trammed about 100 feet and dumped.

Mine Labor, Supplies, and Power

Mine labor. - Two 8-hour shifts are worked at the mine; the day shift is from 8 a.m. to 4:30 p.m. and the night shift from 7 p.m. to 4:30 a.m. The mine superintendent serves as day foreman; the night shift is directed by a night foreman. The surface and underground labor at the mine and its distribution and cost are shown in the following table.

Daily mine labor, June 1936

Occupation	Day	Night	Total	Rate	Daily cost
Surface:					
Blacksmith and compressor man...	1	1	2	$4.00	$8.00
Hoist man........................	1	1	2	4.00	8.00
Topman...........................	1	1	2	3.20	6.40
Ore sorters......................	2	2	4	3.20	12.80
Underground:					
100 level:					
Machinemen.......................	3	2	5	4.00	20.00
Muckers..........................	4	4	8	3.20	25.60
160 level:					
Machineman.......................	1	1	2	4.00	8.00
Machineman helper................	1	1	2	3.20	6.40
220 level:					
Machineman.......................	1	1	2	4.00	8.00
Machineman helper................	1	1	2	3.20	6.40
Muckers..........................	2	2	4	3.20	12.80
Total............................			35		122.40

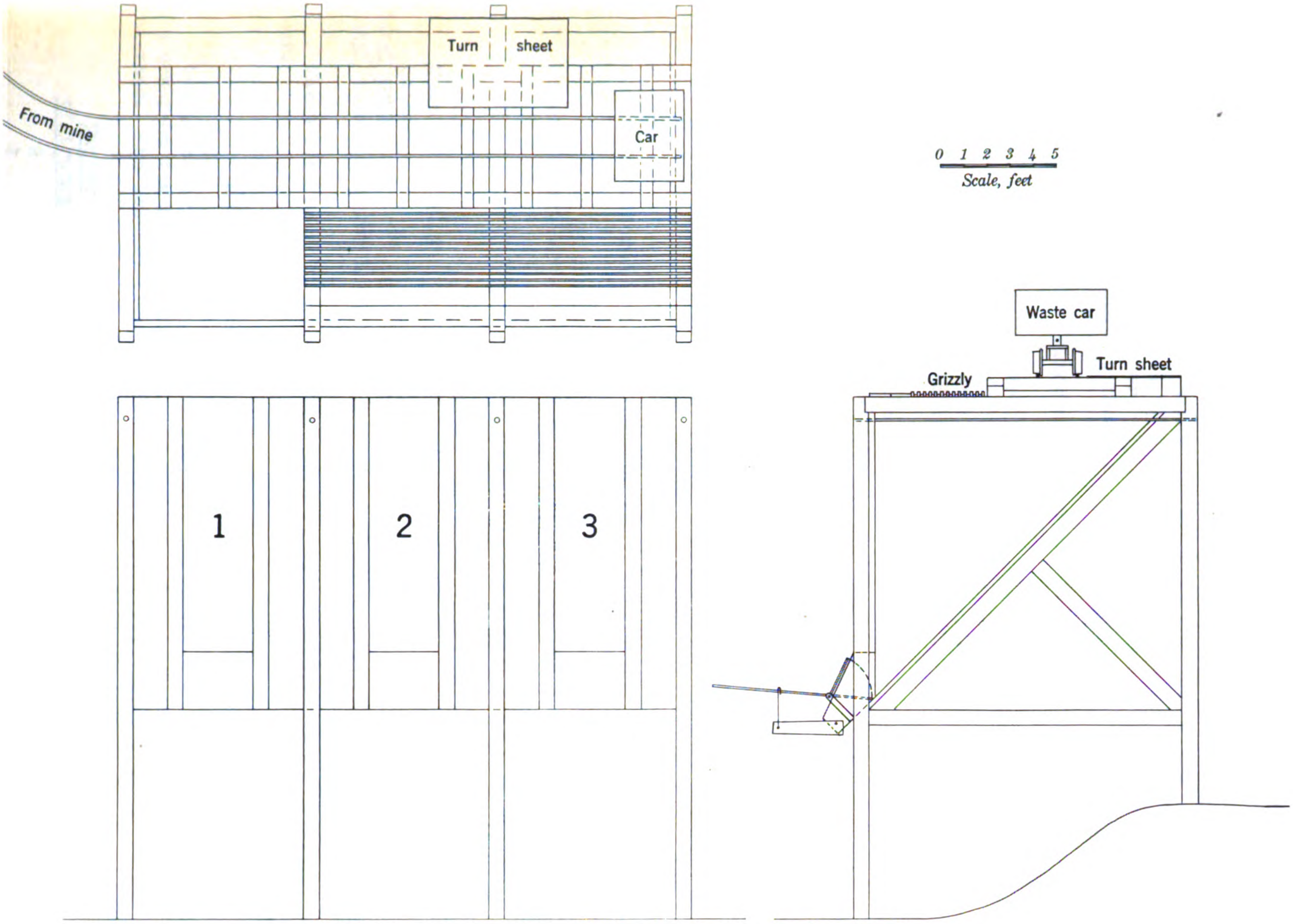

Figure 3.—Mine ore bins showing arrangement for sorting ore.

Men make out their own time slips for each shift or part of a shift worked. The slips show the hours worked and describe and give the location of the work. The mine foreman signs the slips at the end of the shift and enters the data in a time book. Every 15 days the mine time book is turned in to the main office at Boulder. It serves as the basis for compiling the pay-roll and cost-distribution sheets.

Mine supplies. - The following prices are paid for mine supplies:

Powder	per 100 pounds	$13.75
Fuse	per 1,000 feet	6.00
Caps	per 1,000	12.25
Carbide	per 100 pounds	5.60
Steel:		
Solid	cents per pound	14-1/2
Hollow	do.	15-1/2
Timber (round)[1]	cent per diameter-inch per foot of length	1

---

[1] The small round poles for lagging cost 3-1/2 cents per running foot.

Mine power. - Electric power for the mine from March 23 to April 23, 1936 was paid for according to the following schedule:

Demand, hp. = 94.2
Kilowatt-hours metered = 12,960
Pay for:

		Kw.-hr.		
First 30 by 94.2	=	2,826	(first 25 hp. at $1.50	= $37.50
			Balance; 69.2 hp. at $1.25)	= 86.50
				124.00
Next 90 by 94.2	=	8,478	$0.03	= 254.34
Balance	=	1,656	$0.01	= 16.56
Total power	=	12,960		
Total power bill for month				= 394.90

These figures show a power cost of a little over 3 cents per kilowatt-hour.

Surface Transportation of Ore and Concentrates

The trucking division, a separate unit under its own foreman, hauls the ore from the mine to the mill and the concentrates from the mill to the railroad. The company fleet of four trucks comprises the following:

Number of trucks	Rated capacity tons	Usual load in tons
2	3	5-1/2 to 6
1	1-1/2 to 2	5
1	1-1/2	4-1/2

Three of the trucks are in use while one is being overhauled. The trucks are equipped with balloon tires with a heavy cross-ribbed tread that makes the use of chains unnecessary, even in winter. Ore is hauled on two shifts, the day and afternoon shifts of 8 hours each. The crew comprises six drivers and a repairman; they are paid 50 cents an hour from the time they leave Boulder until they return.

Each truck is loaded from the mine ore bins by its driver. The bins are provided with three 36-inch arc gates. Loading time for a truck is about 5 minutes. The haul to the mill is 8 miles over an extremely hilly but well-surfaced dirt road. The road climbs through Salina to Gold Hill, then descends abruptly into Lefthand Canyon where the mill is located. The same road is followed on the return trip to the mine. The maximum grade against the loads is about 21 percent; against the empties, about 30 percent. The trucks can make a round trip in about 2 1/2 hours; they usually make three round trips per shift. Gasoline mileage averages about 4 miles per gallon. Before the company operated its own trucks a contract price of 85 cents per ton was paid for hauling ore from the Grand Republic mine to the mill.

The company trucks are also used to haul concentrates from the mill to the railroad at Boulder, a distance of 21 miles. Concentrates are shipped about once a week; 6 tons are loaded on each truck after it has brought in its last load of ore for the shift. A 36-ton car of concentrates is thus loaded in two shifts. The concentrates are shoveled into the trucks; it usually takes about 30 minutes to load. The concentrates are shipped in end-door railroad cars; the trucks back into the car and dump their loads. Shipment is by rail via the Union Pacific R. R. and the Colorado & Southern Ry. to the Golden Cycle mill at Colorado City, a distance of about 110 miles, or via the Union Pacific R. R. and Denver & Rio Grande Western R. R. to the American Smelting & Refining Co.'s smelter at Leadville, a distance of 194 miles, of which 150 miles are in mountainous territory.

The freight rates on ore and concentrates from Boulder to Colorado City are:

Released valuation per ton....................	Up to $15.00	Over $15.00
Freight per ton..............................	1.50	2.50

The rates from Boulder to Leadville are:

Value per ton	$20.00	$30.00	$40.00	$50.00	$60.00	$70.00	$80.00	$90.00	$100.0
Freight per ton	3.25	3.45	3.50	3.50	3.80	4.10	4.40	4.70	5.0

For values over $100 per ton the rate increases 9 percent for each $25 of additional value.

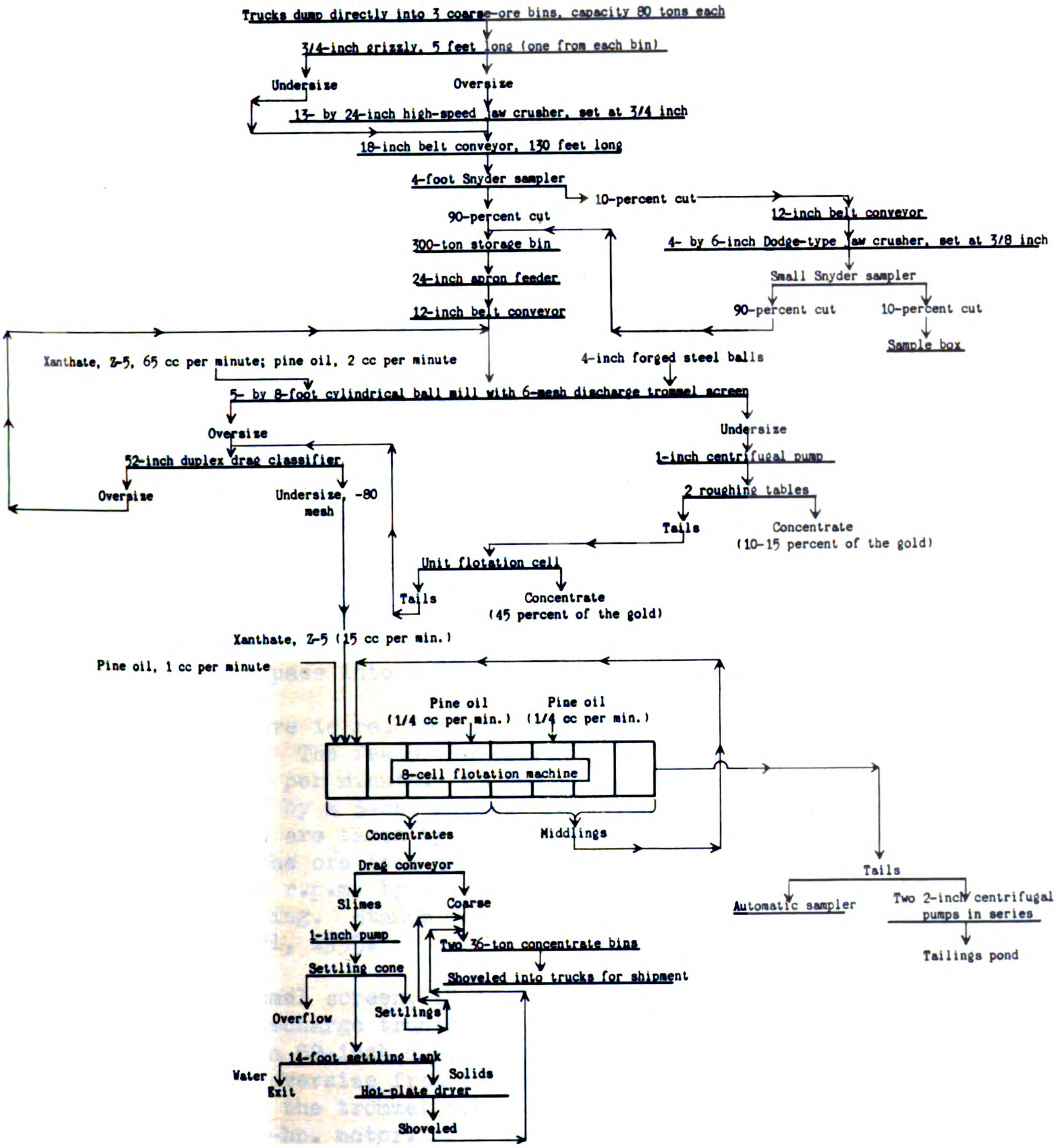
Trucks dump directly into 3 coarse-ore bins, capacity 80 tons each
3/4-inch grizzly, 5 feet long (one from each bin)
Undersize
Oversize
13- by 24-inch high-speed jaw crusher, set at 3/4 inch
18-inch belt conveyor, 130 feet long
4-foot Snyder sampler
10-percent cut
12-inch belt conveyor
4- by 6-inch Dodge-type jaw crusher, set at 3/8 inch
90-percent cut
300-ton storage bin
24-inch apron feeder
12-inch belt conveyor
Small Snyder sampler
90-percent cut
10-percent cut
Sample box
Xanthate, Z-5, 65 cc per minute; pine oil, 2 cc per minute
4-inch forged steel balls
5- by 8-foot cylindrical ball mill with 6-mesh discharge trommel screen
Oversize
Undersize
52-inch duplex drag classifier
1-inch centrifugal pump
Oversize
Undersize, -80 mesh
2 roughing tables
Tails
Concentrate (10-15 percent of the gold)
Unit flotation cell
Tails
Concentrate (45 percent of the gold)
Xanthate, Z-5 (15 cc per min.)
Pine oil, 1 cc per minute
Pine oil (1/4 cc per min.)
Pine oil (1/4 cc per min.)
8-cell flotation machine
Concentrates
Middlings
Tails
Drag conveyor
Automatic sampler
Two 2-inch centrifugal pumps in series
Slimes
Coarse
Tailings pond
1-inch pump
Two 36-ton concentrate bins
Settling cone
Shoveled into trucks for shipment
Overflow
Settlings
14-foot settling tank
Water Exit
Solids
Hot-plate dryer
Shoveled

Figure 4.- Flow sheet of St. Joe mill.

St. Joe Mill

The 100-ton flotation mill of the St. Joe Mining & Milling Co. is in Lefthand Canyon,[8] about half a mile above the town of Rowena.

Milling Method

Trucks dump the ore directly into one of three ore bins through a 12-inch horizontal grizzly of T-rails that extend across the top of the bin. One bin is filled at a time; each bin holds about 15 truck loads, that is, five trips of the haulage fleet of three trucks. Each binful is considered a mill lot for purposes of sampling and for correlation between mine and mill. Figure 4 shows a flow sheet of the mill. At the bottom of each bin is a 20- by 30-inch gate through which the ore is delivered to an inclined grizzly, 5 feet long, with 3/4-inch spaces between the bars. The bins are arranged so that the three grizzlies from the bin gates deliver the ore to a common point. A 13- by 24-inch high-speed jaw crusher set at 3/4 inch receives the ore at this point. The crusher is driven at 360 r.p.m. by a 35-hp. motor using a 10-inch belt drive. The undersize from the grizzlies and the product from the crusher drop onto an 18-inch belt conveyor driven by a 10-hp. motor. The conveyor transports the ore horizontally a distance of 130 feet and discharges it into a 4-foot Snyder sampler. The sampler takes a 10-percent cut, which is delivered by a 12-inch belt conveyor to a 4- by 6-inch Dodge-type jaw crusher set at 3/8 inch. A small Snyder sampler takes a 10-percent cut of the crushed product. The sample is collected in a sample box and riffled down to working size for each mill lot. A 7-hp. motor drives the two samplers and the sample crusher. The rejects from the samplers pass into a 300-ton storage bin.

The crushed ore is removed from the bottom of the storage bin by a 24-inch apron feeder. The feeder is driven by a 3-hp. motor and travels at the rate of 4-1/2 feet per minute. It delivers the ore to a 12-inch belt conveyor, also driven by a 3-hp. motor. Periodic samples constituting the daily heads sample are taken by hand at the discharge of the feeder. The conveyor carries the ore to a 5- by 8-foot cylindrical ball mill which is driven at about 29 r.p.m. by a 125-hp. motor. Four-inch forged-steel balls are used for grinding. Stamps formerly preceded the ball mill; they were discontinued May 21, 1935.

A 6-mesh trommel screen, 13 inches in diameter and 18 inches long, is attached to the discharge trunion of the ball mill. The oversize from the trommel passes to a 52-inch duplex drag classifier, which is driven by a 5-hp. motor. The oversize from the classifier is returned to the ball mill. The undersize from the trommel flows to the intake of a 1-inch centrifugal pump driven by a 5-hp. motor. The pump raises the pulp to two roughing tables, each driven by a 1-1/2-hp. motor. The tables make a finished concentrate that contains from 10 to 15 percent of the gold in the original ore and a tails product that passes to a unit flotation cell. The unit cell is driven by a 10-hp. motor. This cell recovers about 45 percent of the gold in the ore and delivers a tails product to the drag classifier. The overflow of the classifier, minus 80-mesh, contains from 40 to 45 percent of the gold. It is sampled periodically as it passes to the first cell of an 8-cell flotation machine. The impellers of the flotation machine are driven by four 5-hp. motors. Xanthate and pine oil are the only flotation reagents used. They are added to the pulp first in the ball mill and later in the launder leading to the 8-cell flotation machine and in the machine itself. The quantities of the reagents added at various points are shown in the flow sheet (fig. 4).

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[8] In October 1936 a storm destroyed the tailings dam in Lefthand Canyon. The mill was dismantled and the machinery set up in a new mill building erected on the company's mill site at Valmont. (See p. 5.)

The first four cells of the flotation machine make a concentrate. The froth from the last four cells is fed back to the first cell. The tails from the last cell are automatically sampled by a device that takes a cut every 12 minutes, which amounts to about 1 gallon per shift. The tails, after being sampled, are raised 60 feet by a 2-inch centrifugal pump and delivered to a small tank. The pump is run at 1,750 r.p.m. by a 10-hp. motor. Another 2-inch centrifugal pump, driven at 1,160 r.p.m. by a 10-hp. motor, pumps the tails from the small tank to the tailings pond. The cost of tailings disposal is estimated by the company to be about 15 cents per ton.

The concentrate from the first four cells of the flotation machine is carried in a short launder to a drag conveyor driven by a 3-hp. motor. The coarse material is dragged up an incline and dumped into one of two 36-ton concentrate bins. The slimes are pumped into a settling cone by a 1-inch centrifugal pump driven by a 3-hp. motor. The settlings from the cone pass into the concentrate bins. The overflow from the cone flows into a 14-foot settling tank. The solids that settle out in the tank are dried on a hot plate and shoveled into the concentrate bins. The concentrates in the bins contain about 12 percent moisture. A pipe sample weighing about 10 pounds is taken from each truck load of concentrates at the company's sampling plant in Boulder. The fairly clear water overflowing from the settling tank is allowed to run into Lefthand Creek.

The ratio of concentration ranges from 12 : 1 to 20 : 1.

The mill uses about 4 tons of water per ton of ore. During the winter it is sometimes necessary to return water for reuse in the mill; otherwise water is not used over again.

A report of mill operations is made for each shift. The report for the day shift on April 30, 1936, was as follows:

St. Joe mill - daily shift report

Shift, day

Date, April 30, 1936

Time	8	9	10	11	12	1	2	3
Solids in classifier overflor..percent	19.5	19.5	20	19.5	19.5	19.5	20	19.5
Soda ash, ball mill.........oz.......								
Lead nitrate, ball mill.... cc.								
Xanthate, ball mill........ do.	52	52	52	52	52	52	52	52
Pine oil, ball mill........ do.	2	2	2	2	2	2	2	2
Drops aerofloat, ball mill...........								
Lead nitrate, conditioner...cc.								
Xanthate, conditioner.......do.	15	15	15	15	15	15	15	15
Pine oil, 8-cell............do.	2	2	2	2	2	2	2	2
Drops aerofloat, 8-cell..............								
Weight of sample.....................	36	36	36	36	36	36	36	36
Feed off...............minutes.......								
Balls added, 4-inch..................							40	

(Signed by shift boss)

The percentage of solids in the classifier overflow is determined from a pulp-consistency table that has been worked out for the convenience of the mill superintendent. The table is calculated for Grand Republic ore, which has a specific gravity of about 2.7. A small cylinder with an inside diameter of 2-1/8 inches and a depth of 7-1/4 inches is first weighed full of water. This weight is used as a counterpoise to give a zero reading on the scales. To determine the percentage of solids in the pulp at any time, the cylinder is filled with the pulp and weighed. The figure in the following pulp-consistency table opposite the weight of the pulp is the percentage of solids in the pulp.

Pulp consistency table for Grand Republic ore

Weight of pulp, grams	Percent solids	Weight of pulp, grams	Percent solids	Weight of pulp, grams	Percent solids	Weight of pulp, grams	Percent solids
44.5	15.0	63.3	20.5	83.7	26.0	103.8	31.0
46.2	15.5	65.1	21.0	85.6	26.5	105.9	31.5
47.9	16.0	66.9	21.5	87.6	27.0	108.0	32.0
49.5	16.5	68.8	22.0	89.6	27.5	110.1	32.5
51.2	17.0	70.6	22.5	91.6	28.0	112.2	33.0
52.9	17.5	72.4	23.0	93.5	28.5	114.4	33.5
54.6	18.0	74.2	23.5	95.6	29.0	116.6	34.0
56.3	18.5	76.1	24.0	97.6	29.5	118.8	34.5
58.1	19.0	78.0	24.5	99.7	30.0	121.0	35.0
59.8	19.5	79.9	25.0	101.7	30.5		
61.6	20.0	81.8	25.5				

The "Weight of sample" shown on the daily shift report is the weight in pounds of the entire discharge of the 24-inch apron feeder for a period of 15 seconds. By means of a tonnage table the weight of sample is readily converted into tons per day. According to the tonnage table, a weight of 36 pounds indicates a rate of feed of about 104 tons per day.

Mill Labor

The mill crew comprises 11 men, as follows:

Daily mill labor

Occupation	Rate	Shift Day	 After-noon	 Night	Total shifts	Cost
Flotation man..................	$4.00	1	1	1	3	$12.00
Ball-mill man and oiler........	3.75	1	1	1	3	11.25
Repairman......................	4.00	1			1	4.00
Crusher-and-sample man.........	3.50	2			2	7.00
Tailings-pond man..............	3.50	2			2	7.00
Total per day..............		7	2	2	11	41.25

Mill Power

Electric power is brought to the mill at 23,000 volts from the Public Service Co. of Colorado plant at Valmont, a distance of about 10 miles. At the mill the voltage is stepped down to 440 volts for the motors and to 110 volts for lighting. Virtually all the machines are driven by individual motors using multiple V-belt drives.

Electric power for the mill is paid for according to the following schedule:

Fixed charge = 1.5 x hp. demand (average of three 3-minute peaks during month).

Pay for first 100 kw.-hr. x hp. demand at $0.015 per kw.-hr.
Pay for balance at 0.007 per kw.-hr.
Transformer loss = 1,700 kw.-hr.

If this schedule is applied to the power used by the mill from March 23 to April 23, 1936:

54,960 kw.-hr. metered
1,700 kw.-hr. transformer loss
56,660 total kw.-hr.

Peak demand for month was 164.1 hp.	
Fixed charge = 1.5 x 164.1 =	$246.15
Pay for 100 x 164.1 = 16,410 kw.-hr. at $0.015 =	246.15
Balance of 40,250 kw.-hr. at 0.007 =	281.75
Transformer rental =	23.00
Total power bill for month	797.05

According to the above figures power for the mill costs about $0.0145 per useful kilowatt-hour.

Metallurgical Statistics

The metallurgical report for the mill for December 1935 gives the following information for the year 1935:

Dry tons of ore milled	30,393.549
Concentrates produced	1,700.614
Number of shifts operated	1,029.539
Dry tons of ore milled per shift	29.522
Ratio of concentration	17.872
Percent moisture in concentrates	12.248

	Assays (oz. per ton)		Total ounces of metal	
	Gold	Silver	Gold	Silver
Heads	0.240	0.214	7,292.697	6,489.912
Concentrates	3.898	3.276	6,629.821	5,571.881
Tails	.0231	.032	662.876	918.031

Actual recovery of gold	percent	90.910
Actual recovery of silver	do	85.854

Supplies used:

		Total	Per ton
Amyl xanthate	pounds	3,975	0.131
Ethyl xanthate	do	3,885	.128
Pine oil	do	3,921	.129
Lead nitrate	do	3,513	.116
Soda ash	do	11,900	.392
Lime	do	1,600	.053
Grinding balls	do	103,440	3.403
Electric power: kw.-hr.		802,364	26.399
Demand	horsepower	165.6	----

The number of shifts operated (1,029.539) represents 94 percent of the total time. The 6 percent lost time was accounted for as follows:

	Percent of lost time
Repairs	1/ 55.9
Holidays	21.1
Lack of ore	20.8
Power off	2.2
	100.0

1/ Including 3 shifts on May 21, when the stamps, which had preceded the ball mill, were cut out of the mill circuit.

For the purpose of comparison the metallurgical report for the first 5 months of 1936 is given below:

Dry tons of ore milled	12,671.479
Hours operated	3,167.25
Percent running time	86.822
Dry tons of ore milled per hour	4.001
Hours lost time	480.75
By holidays	75.00
By lack of ore	260.00
By repairs	139.75
By power off	6.00
Man shifts	1,752
Dry tons of ore milled per man shift	7.233
Tons of concentrates produced	887.861
Percent moisture in concentrates	12.506
Ratio of concentration	14.272

	Assays (oz. per ton)		Total ounces of metal	
	Gold	Silver	Gold	Silver
Heads	0.219	0.366	2,781.087	4,637.973
Concentrates	2.851	3.013	2,531.160	2,675.077
Tails	.021	.167	249.927	1,962.896

Actual recovery of gold..........percent.....91.013
Actual recovery of silver..........do........57.678

Supplies used:

		Total	Per ton
Amyl xanthate	pounds	1,425	0.112
Ethyl xanthate	do	575	.045
Pine oil	do	1,783	.141
Lead nitrate	do	0	.000
Soda ash	do	450	.035
Lime	do	22,600	1.784
Grinding balls	do	45,500	3.591
Electric power	kw.-hr.	319,478	25.214
Demand	horsepower	169.5	

Marketing Concentrates

A 70-pound sample of the concentrates was assayed in April 1936 and showed the following composition:

Gold	ounces per ton	3.66
Silver	do	2.24
Lead	percent	0
Copper	do	0
Iron	do	25.58
Sulphur	do	23.30
Arsenic	do	.93
Insoluble	do	43.40

The specific gravity of the concentrates was 3.29.

The following figures indicate the method of settlement for a lot of concentrates shipped to the Golden Cycle mill in June 1936:

Wet weight, pounds	Percent moisture	Dry weight, pounds	Gold, ounces per ton	Silver, ounces per ton
103,280	14.0	88,820	2.83	1.25
1/ 51.64		1/44.41		

1/ Tons.

Payment per ton		Gross value	
Gold: 100 percent at $32.26	$91.30	Gold	$4,054.63
Silver: 50 percent at $0.77	.48	Silver	21.32
Total per ton	91.78	Total	4,075.95

Charges:

Moisture - excess over 10 percent at $0.05 per ton, 4 at $0.05 x 44.41 tons	$ 8.88	
Treatment - 44.41 tons at $5.75	255.36	
Freight - 51.64 tons at $2.50	129.10	$393.34
Net returns		3,682.61

The figures below show the method of settlement for a lot of concentrates shipped to the American Smelting & Refining Co.'s Arkansas Valley plant at Leadville in December 1935:

Wet weight, pounds	Percent moisture	Dry weight, pounds	Assay	
			Gold, ounces per ton	Silver, ounces per ton
68,060 1/34.03	12.5	59,553 1/29.7765	4.35	3.1

1/ Tons.

(Frozen weight, 68,580 pounds)

Payment per ton		Gross value	
Gold: 100 percent at $32.81825....	$142.76	Gold.....	$4,250.89
Silver: 95 percent at $0.55.......	1.62	Silver...	48.24
Total per ton................	144.38	Total...	4,299.13

Charges:

Moisture....................................	$4.25	
Treatment - 29.7765 tons at $8.50.........	253.10	
Freight - 34.29 tons at $5.00.............	171.45	$428.80
Net returns..................................		3,870.33

Custom Sampling Plant and Metallurgical Laboratory

Sampling Plant

The Boulder Ore Sampling Works was built at Eighth and Pearl Streets in Boulder many years ago. It was purchased by the St. Joe Mining & Milling Co. and opened for business under the new management on June 1, 1933.

Most mine lots received by the sampler comprise one truck load of ore. After the truck is weighed it is backed into the sampler building, and the ore is shoveled onto a 4- by 2-foot grizzly with 3/4-inch spaces between the bars. A flow sheet of the sampling plant is shown in figure 5. The oversize from the grizzly slides into a 5- by 10-inch jaw crusher of the Blake type, set at 1 inch. The crusher discharges into a set of 14- by 27-inch rolls set at 5/8 inch. The crushed ore from the rolls joins the undersize from the grizzly in the feed box of a bucket conveyor with 54 buckets; it raises the fine ore a distance of about 40 feet. The ore then enters a 3- by 3-foot trommel equipped with a 5/8-inch screen. The oversize from the trommel drops back to the rolls. The undersize from the trommel passes

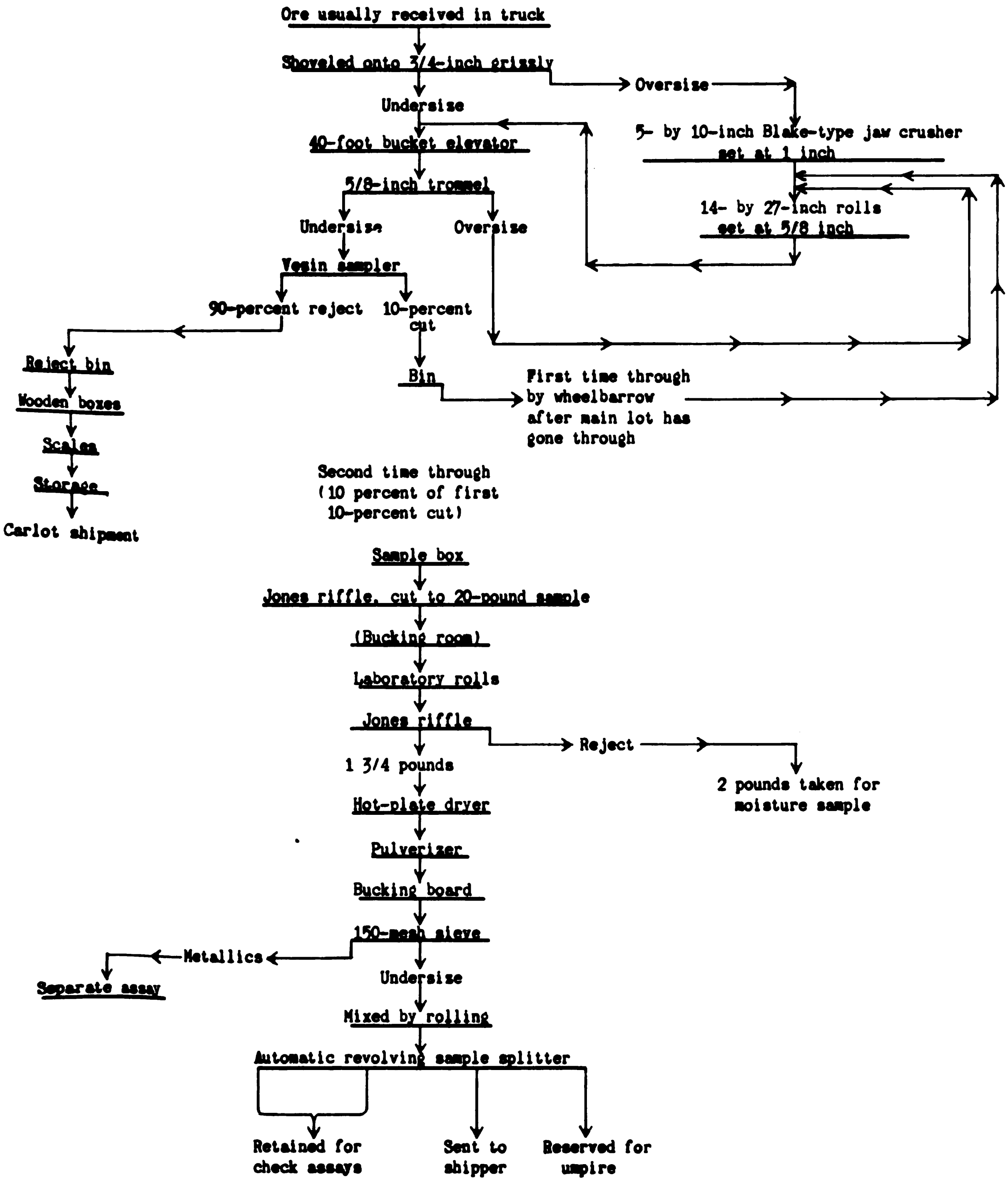
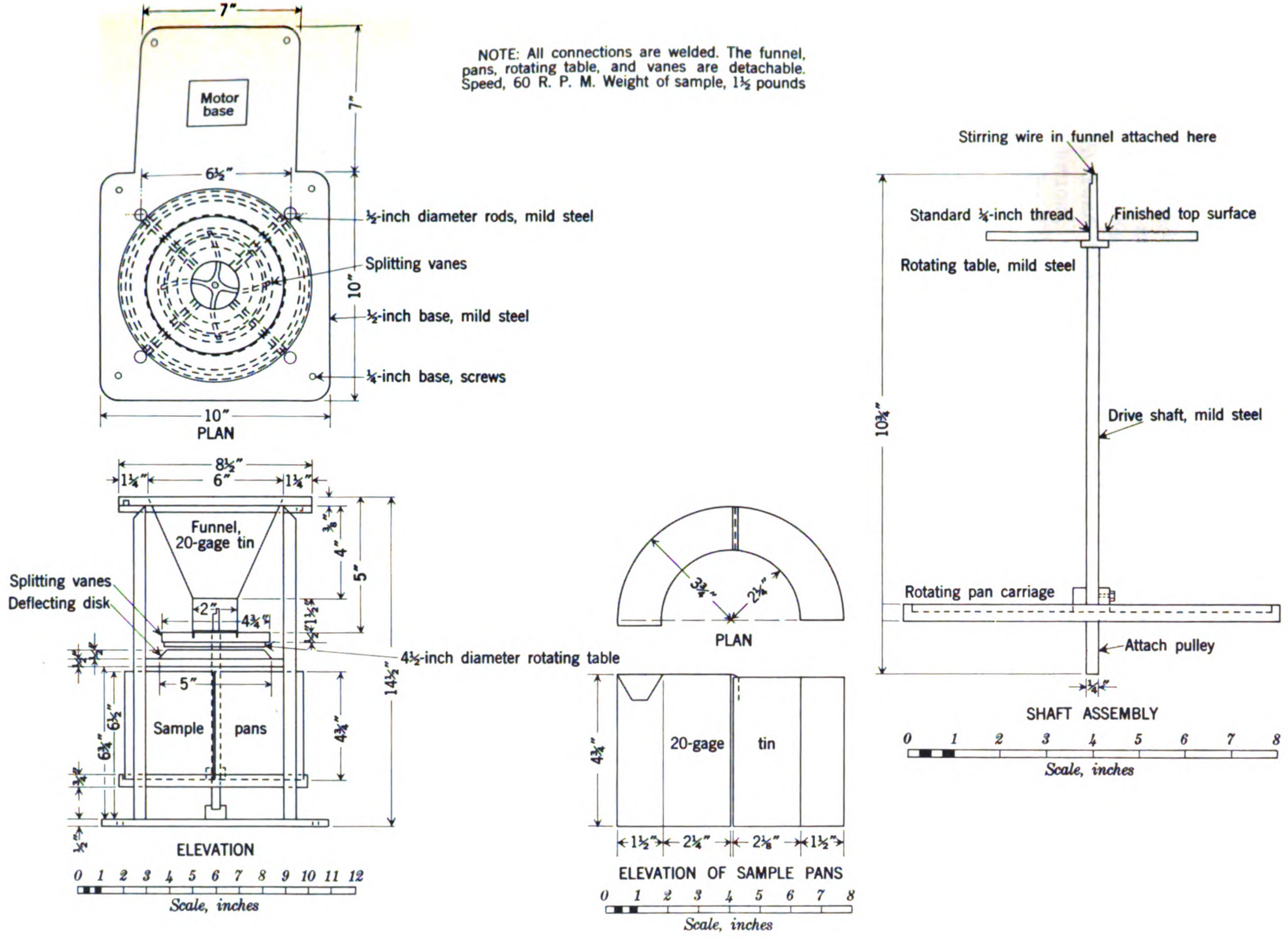

Ore usually received in truck
Shoveled onto 3/4-inch grizzly
Oversize
Undersize
5- by 10-inch Blake-type jaw crusher set at 1 inch
40-foot bucket elevator
5/8-inch trommel
14- by 27-inch rolls set at 5/8 inch
Undersize
Oversize
Vezin sampler
90-percent reject
10-percent cut
Reject bin
Bin
Wooden boxes
First time through by wheelbarrow after main lot has gone through
Scales
Storage
Carlot shipment
Second time through (10 percent of first 10-percent cut)
Sample box
Jones riffle, cut to 20-pound sample
(Bucking room)
Laboratory rolls
Jones riffle
Reject
1 3/4 pounds
2 pounds taken for moisture sample
Hot-plate dryer
Pulverizer
Bucking board
150-mesh sieve
Metallics
Separate assay
Undersize
Mixed by rolling
Automatic revolving sample splitter
Retained for check assays
Sent to shipper
Reserved for umpire

Figure 5.- Flow sheet of Boulder Ore-Sampling Works.



NOTE: All connections are welded. The funnel, pans, rotating table, and vanes are detachable. Speed, 60 R. P. M. Weight of sample, 1½ pounds

Figure 6.—Sample-splitting machine.

into a Vezin sampler, which takes a 10-percent cut. This cut drops into a sample bin. The 90-percent reject falls into a reject bin from which it is later drawn out into 2-ton wooden boxes for storage. Each box is supported on a light angle-iron framework about 18 inches high. A specially constructed hand truck fits under the framework and raises both box and framework for transportation to any part of the sampler floor. The boxes of ore are weighed and arranged in rows with aisles between. Shipment is made by carload lot. To load the ore into a railroad car, the boxes are picked up by the special truck, wheeled into the car, and dumped. One end of the box is hinged at the top and held closed by a finger at the bottom. The finger is released by means of a rod that runs under the box and is attached to a lever at the opposite end of the box; the operation is similar to that of dumping the ordinary end-dump mine car.

After the main lot of ore has passed through the mill the 10-percent cut in the sample bin is transferred by wheelbarrow back to the rolls. It follows the same flow sheet from that point, and a second 10-percent cut (1 percent of the original lot) is delivered to the sample bin. This sample is run into a sample box and riffled down to about 20 pounds. It is then taken to the bucking room. There it is put through a set of laboratory rolls and riffled down to about 1-3/4 pounds. Two pounds of the reject are taken for a moisture sample. The 1-3/4-pound sample is dried on a hot-plate dryer and put through a pulverizer. It is then bucked down to minus 150-mesh; metallics caught on the sieve are saved for a separate assay. The sample is mixed by rolling and is finally put into an electrically driven revolving sample splitter (fig. 6) which divides it into four equal parts. Two of the quarters are saved by the company for check assays, one quarter is sent to the shipper, and one quarter is reserved for umpire.

Power for the sampling plant is furnished by a 440-volt, 25-hp. motor running at 600 r.p.m. The motor drives a line shaft by means of a 10-inch belt; all the machines are belt-driven from the line shaft.

During the winter only one man is employed in the sampler; he also assists the metallurgist in the laboratory. He receives $3.20 per day. To handle the increased shipments in the spring and summer an additional man is employed; he receives $3.00 per day.

Charges made by the sampler and the basis of payment for lots of ore are as follows:

Boulder Ore Sampling Works
of
St. Joe Mining & Milling Co.

Schedule of Rates

Sampling:	Per ton	Minimum
When value per ton is under $8.00	$0.25	$2.50
When value per ton is $8.00 to $15.00	1.25	3.75
When value per ton is $15.00 to $40.00	1.50	4.50
When value per ton is over $40.00	2.00	5.00
Freight (Boulder to Colorado City, via Union Pacific R.R. and Colorado & Southern Ry.):		Pounds
When value per ton is under $15.00	1.50	40,000
When value per ton is $15.00 and over	2.50	60,000
Treatment:		
When value per ton is under $8.00	2.50	
When value per ton is $8.00 to $10.00	3.00	
When value per ton is $10.00 to $15.00	4.00	
When value per ton is $15.00 to $20.00	4.50	
When value per ton is $20.00 to $40.00	5.50	
When value per ton is over $40.00	6.00	

Basis of Payments

Gold: Pay 85 percent of mint price.

Silver: No payment for silver when under 1 ounce per ton; pay 85 percent of market price on the following basis:

Ore content, ounces	Percent paid for
1 to 5	50
5 to 10	65
10 to 20	75
20 to 50	85
50 to 100	90

Lead and copper: Sampler settlement is the same as that by the Golden Cycle mill, to which shipment is made.

Payment will be made in full on the 1st, 11th, and 21st day of the month for ore agreed upon by the close of the preceding day.

Miscellaneous

When umpiring is done, shipper pays if less than 3 tons dry weight and loser pays when over 3 tons.

Rates subject to change without notice.

September 25, 1935.

During 1935 the sampler handled 2,493.71 tons of ore, an average of 207.81 tons per month. It was operated 308 days during the year. The operations of the sampler in 1935 were as follows, excluding operations on its own dump, an accumulation over many years of 243.54 tons that were sampled and marketed in 1935.

Sampler operation for 1935

Wet tons of ore received...........................	2,250.17
Total cost of operation............................	$3,290.35
Operating cost per ton of ore received...........	1.462
Total net profit...................................	2,599.41
Net profit per ton of ore received...............	1.156

Metallurgical Laboratory

The laboratory building is located near the sampler; an office in the front end serves both the metallurgical and sampling departments. Directly behind the office is the research laboratory equipped with a small batch ball mill, a 2,000-gram flotation machine, and other apparatus for making flotation and cyanidation tests. The assay laboratory occupies an adjoining room. Facilities are available for making both fire and wet assays, but as the routine company work and most of the custom samples are run for the precious metals only, most of the assaying is done by fire methods. A large muffle furnace heated by natural gas is used for making crucible assays and for cupeling.

Assays are made on the following types of samples:

1. Mine samples, taken by the mine foreman from stopes or development headings.

2. Mill samples: Daily heads, classifier overflow, and tails from each shift; mill lots.

3. Custom samples, as submitted. A charge of 50 cents is made for the determination of gold and silver on the same sample.

4. Marketing samples, sampler control on shipments.

5. Sampler control on ore purchased.

6. Research samples.

7. Composite samples, checks, and miscellaneous.

To accommodate the widely different samples two general fluxes are used, one reducing and the other nonreducing. The nonreducing flux contains:

	Pounds
Sodium bicarbonate..............................	20
Powdered borax..................................	20
Litharge..	25

The quantities indicated above are mixed in a barrel churn by the metallurgist's assistant. The reducing flux contains 2-1/2 pounds of flour in addition to the above ingredients. No nails are used.

One cc of a standardized solution of silver nitrate is added to each crucible. The standardized solution is made by dissolving 2 grams of silver nitrate crystals in about 500 cc of water. One cc of the newly made solution is added to a dummy or blank crucible charge. The silver bead obtained is used as a counterpoise on the weight pan when weighing gold and silver beads obtained from subsequent assays. The silver nitrate solution is made up as needed; it is standardized once a week. Greater accuracy is claimed for this method of introducing silver than for the more common method of using metallic silver.

During 1935 the assay laboratory averaged about 50 assays a day; nearly half of them were for the St. Joe mill. The cost of assays per ton of ore mined and milled in 1935 was $0.097. Muffle expense was kept down by keeping the pilot light burning under the muffle at night; this prevented the muffle from cracking when cooling. The muffle now in the furnace cost $17.20, but it has been in use nearly a year and shows no signs of breaking down. Further assay economy resulted from changing the pulverizer plates one at a time instead of in pairs.

Costs

A complete cost record is kept. Tables 1 to 7 are from the auditor's report for the year ending December 31, 1935.

TABLE 1. - Mining expense for year ended December 31, 1935

	Amount	Mining cost per ton
Grand Republic mine (28,515.514 dry tons milled):		
Labor:		
Superintendence	$ 4,262.50	$0.149
Machine runners	8,164.05	.286
Tenders	1,054.80	.037
Muckers	14,125.30	.496
Hoist operators	2,410.50	.085
Topmen	2,002.45	.071
Miscellaneous	891.75	.031
Engineers and blacksmith	2,728.75	.096
Holidays	352.20	.012
Moving compressor	518.19	.018
Supplies:		
Powder	6,844.33	.241
Fuse	997.46	.035
Caps	337.58	.012
Drill steel	1,428.56	.050
Other supplies	1,067.04	.037
Other costs:		
Power	3,590.38	.126
Compensation insurance	1,775.11	.062
Tools and repairs	1,660.65	.058
Freight and truck expense	105.73	.004
Surveying	252.90	.009
Miscellaneous	116.39	.004
Moving compressor	92.94	.003
Depreciation	2,838,22	.099
Other insurance	71.91	.002
Taxes	242.24	.008
Ore in bins inventory	1/833.64	1/.029
Proportion of general and administrative expense	9,640.54	.339
Proportion of laboratory expense	512.28	.018
Road expense	2,150.79	.075
Total Grand Republic expense	69,401.90	2.434
Other mines (1,800.409 dry tons milled):		
Direct expense not detailed	11,885.65	6.602
General expense	2,213.70	1.230
Laboratory expense	296.61	.165
Royalties expense	56.56	.030
Total other mines	14,452.52	8.027
Total mining expense	83,854.42	

1/ Credit.

TABLE 2. - Expense of hauling ore and concentrates for year ended December 31, 1935

	Amount
Labor:	
Supervision	$267.96
Drivers	7,434.54
Repairs	639.65
Holidays	98.40
Supplies:	
Gasoline	5,314.48
Oil and grease	607.12
Tires	1,724.56
Other costs:	
Tire repair	81.65
General repair	2,387.54
Compensation insurance	175.82
Licenses and other insurance	311.81
Storage	167.85
Miscellaneous	163.26
Depreciation	3,088.68
Taxes	116.80
Contract trucking	2,407.62
Proportion of general and administrative expense	2,225.70
Total hauling expense	27,213.44

Distribution on basis of ton-miles:	Percent	Amount	Cost per ton
Ore hauling:			
Grand Republic mine	92.098	$25,063.03	$0.879
Other mines	2.590	704.83	.391
Total ore hauling	94.688	25,767.86	
Concentrate hauling:			
Grand Republic mine	4.963	1,350.60	1/.047
Other mines	.349	94.98	1/.053
Total concentrate hauling	5.312	1,445.58	
Total, both ore and concentrates	100.000	27,213.44	

1/ Cost per ton of ore.

TABLE 3. - Milling expense for year ended December 31, 1935

	Amount	Cost per ton
Labor:		
Superintendence	$1,975.00	$0.065
Crusher operators	2,897.67	.096
Stamp mill operators	1,434.57	.047
Ball mill operators	2,388.63	.079
Flotation operators	4,118.29	.136
Repairs	1,722.45	.057
Concentrate handling	256.13	.008
Miscellaneous labor	254.75	.008
Tailings pond labor	1,548.76	.051
Holidays	120.50	.004
Labor sold	[1] 522.08	[1] .017
Reagents:		
Lead nitrate	526.38	.017
Xanthates	1,456.00	.048
Pine oil	337.71	.011
Grinding balls	2,507.08	.083
Aerofloat	15.00	.001
Soda ash	337.03	.011
Lime	17.00	.001
Other costs:		
Power	10,791.17	.356
Repairs	3,030.58	.100
Compensation insurance	259.58	.009
Miscellaneous	246.17	.008
Heating fuel	526.45	.017
Freight and trucking	570.98	.019
Stamps, shoes and dies	712.54	.024
Tailings pond	218.63	.007
Depreciation	5,835.07	.192
Xanthate royalties	303.93	.010
Taxes	308.10	.010
Proportion of general and administrative expense	4,407.72	.145
Proportion of laboratory expense	2,580.86	.085
Total milling expense	51,182.65	1.688

Distribution on basis of tons of concentrate milled:	Percent	Amount	Cost[2] per ton
Grand Republic	93.43	$47,819.95	$1.677
Other mines	6.33	3,239.86	1.800
Total to mining expense	99.76	51,059.81	1.684
Sampler	.24	122.84	1.485
Total milling expense	100.00	51,182.65	1.688

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[1] Credit.

[2] Cost per ton of ore.

TABLE 4. - Net Profit from sampler operation for year ended December 31, 1935

Income:		
Ore sales	$23,637.45	
Sampling charges	172.39	
Bullion sales	299.01	
Gross sales	24,108.85	
Cost of ore purchased	17,716.15	
Gross income		$6,392.70
Expense:		
Labor:		
Supervision	197.15	
General labor	1,343.34	
Other costs:		
Power	306.40	
Tools and repairs	360.76	
Compensation insurance	30.10	
Licenses and other insurance	119.13	
Miscellaneous	38.02	
Depreciation	155.51	
Taxes	82.40	
Proportion of general and administrative expense	449.29	
Proportion of laboratory expense	1,067.58	
Cost on ore sent to mill	122.84	
Total expense		4,272.52
Net operating profit		2,120.18
Other income:		
Sales from sampler dump	1,854.97	
Less labor on dump	163.22	
Total other income		1,691.75
Net profit from sampler operation		3,811.93

Custom Assaying

Assay sales	964.65
Less laboratory expense	665.45
Net profit from custom assaying	299.20

TABLE 5. - Laboratory expense for year ended December 31, 1935

Labor:	
Assaying	$1,650.22
Bucking room	512.49
Miscellaneous	18.15
Supplies:	
Chemicals	922.07
Supplies	5.00
Replacements	192.62
Other costs:	
Power	229.04
Gas	463.76
Compensation insurance	34.92
Other insurance	4.13
Miscellaneous	301.26
Depreciation of buildings and equipment	192.90
Taxes	41.20
Proportion of general and administrative expense	555.02
Total	5,122.78

Distribution on basis of crucibles used:	Percent	Amount
Grand Republic mine	10.00	$512.28
Other mines	5.79	296.61
Mill	50.38	2,580.86
Sampler	20.84	1,067.58
Custom assaying	12.99	665.45
Total	100.00	5,122.78
Cost per crucible		.314

TABLE 6. - General and administrative expense
for year ended December 31, 1935

Office salaries and wages	$3,217.70
General management	7,283.58
Telephone and telegraph	576.17
Postage	15.93
General insurance	158.97
Compensation insurance, office, and executive	129.96
Employees' contributory insurance (company's share)	376.20
Auto expense	325.30
Dues and subscriptions	227.01
Legal	782.75
Donations	82.50
Printing	97.40
Bank exchange	241.84
Office supplies and expense	119.46
Miscellaneous	829.73
Taxes	832.63
Office heat	46.09
Depreciation of buildings and equipment	313.47
Interest	3,736.89
Bad debts	98.39
Total	19,491.97

Distribution on basis of direct labor cost:

	Percent	Amount
Grand Republic mine expense	49.459	$9,640.54
Other mines expense	11.357	2,213.70
Mill	22.613	4,407.72
Ore hauling	11.418	2,225.70
Laboratory	2.848	555.02
Sampler	2.305	449.29
Total	100.000	19,491.97

TABLE 7. - Net profit from mining and milling for year ended December 31, 1935

	Grand Republic mine	Per ton	Other properties	Per ton	Total	Per ton
Dry tons milled	28,515.514		1,800.409		30,315.923	
Value of ore to mill:						
Value of gold in crude ore					$235,114.62	$7.755
Value of silver in crude ore					2,895.39	.096
Total value of ore to mill					238,010.01	7.851
Tailings loss:						
Value of gold lost in tailings					21,371.92	.704
Value of silver lost in tailings					409.58	.014
Total tailings loss					21,781.50	.718
Gross value of concentrates:						
Gross value of gold settled for	$207,913.74	$7.291	$5,828.96	$3.237	213,742.70	7.051
Gross value of silver settled for	1,620.47	.057	865.34	.481	2,485.81	.082
Total value of concentrates	209,534.21	7.348	6,694.30	3.718	216,228.51	7.133
Marketing expense:						
Freight and trucking	5,906.70	.207	414.07	.230	6,320.77	.209
Treatment	10,219.10	.359	647.13	.359	10,866.23	.358
Umpiring and inspection	86.30	.003			86.30	.003
Total marketing expense	16,212.10	.569	1,061.20	.589	17,273.30	.570
Net value of concentrates	193,322.11	6.779	5,633.10	3.129	198,955.21	6.563
Royalties collected from lessees	593.32	.021	30.62	.017	623.94	.020
Gross profit	193,915.43	6.800	5,663.72	3.146	199,579.15	6,583
Mining and milling expense:						
Mining expense	69,401.90	2.434	14,452.52	8.027	83,854.42	2.766
Hauling crude ore to mill	25,063.03	.879	704.83	.391	25,767.86	.850
Milling expense	47,819.95	1.677	3,239.86	1.800	51,059.81	1.684
Hauling concentrates to railroad	1,350.60	.047	94.98	.053	1,445.58	.048
Total mining and milling expense	143,635.48	5.037	18,492.19	10.271	162,127.67	5.348
Net profit from mining and milling before depletion	50,279.95	1.763	1/12,828.47	1/7.125	37,451.48	1.235
Depletion, percentage basis	23,075.55	.809			23,075.55	.761
Net profit from mining and milling after depletion	27,204.40	.954	1/12,828.47	1/7.125	14,375.93	.474

1/ Deficit.

Table 8 and 9 are a recapitulation of the auditor's figures made by the author to conform to the standard Bureau of Mines forms.

Indirect costs that do not come within the scope of table 8 are:

	Cost per ton
Depreciation	$0.099
Insurance other than compensation insurance	.002
Taxes	.008
General, administrative, and laboratory expense and miscellaneous	.361
Road expense	.075
	.545
Total direct costs from table 8	1.918
	2.463
Less credit for ore in bins inventory	.029
Total mining expense per ton of ore milled	2.434

TABLE 8. - Summary of mining costs[1]

(Grand Republic mine for year ended December 31, 1935.
Tons of ore milled[2] during period, 28,515.514.
Mining method, open stoping)

Underground costs per ton of ore milled[2]

	Labor	Supervision and surveying	Power	Drill steel	Explosives	Other supplies	Total
Development and mining.........	0.819		0.126	0.050	0.288		1.283
Underground transportation.....	.085						.085
General underground expense....	.043	0.009					
Surface expense directly applicable to underground operation..........................	.185	.149				0.099 .003	.488
Compensation insurance.........	.062						.062
	1.194	0.158	0.126	0.050	0.288	0.102	1.918

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[1] The figures in this table have been taken from an auditor's report and are grouped according to the author's best judgment. Their distribution in this table is necessarily subject to the inherent weakness of any attempt to generalize, for the purpose of engineering comparison, figures that have been computed for a definite object in accounting.

[2] "Ore milled" rather than "ore hoisted" has been used in this table in order to be in agreement with the auditor's statements. Ore milled represents about 90 percent of ore hoisted.

TABLE 9. - Summary of milling costs[1]

Milling plant: St. Joe. Period covered: Year ended Dec. 31, 1935. Milling methods- Gravity concentration
Flotation

Tons of ore treated, 30,315.923. Ounces of gold and silver produced: Gold - 6,027.2
Silver - 4,783.7

Milling cost per ton of ore milled

	Operating labor	Super-vision	Power	Supplies	Reagents	Repairs		Miscel-laneous	Total
						Labor	Supplies		
Breaking..................	$0.096								0.096
Stamp milling..............	.047			0.024					.071
Ball milling...............	.079			.083					.162
Flotation..................	.136				0.099				.235
Concentrate handling.......	.008								.008
Tailing disposal...........	.051			.007					.058
Not distributed............	.012	0.065	0.356	.027		0.057	0.100	0.017	.634
Compensation insurance.....	.009								.009
Labor sold.................	-.017								-.017
Total..................	0.421	0.065	0.356	0.141	0.099	0.057	0.100	0.017	1.256

Depreciation, taxes, and general administrative and laboratory expense.......................... 0.432

Total milling cost per ton of ore milled... 1.688

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[1] The figures in this table have been taken from an auditor's report and are grouped according to the author's best judgment. Their distribution in this table is necessarily subject to the inherent weakness of any attempt to generalize, for the purpose of engineering comparison, figures that have been computed for a definite object in accounting.